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by

Wang Rongrui

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AUTHOR: Wang Rongrui

This article, by way of a simple summary, introduces certain aspects of the U.S. "Star Wars" program which have undergone developments recently as well as experimentation planned in the future.

In 1984, the U.S. Defense Department set up a Strategic Defense authority in order to carry out the "Star Wars Program" and put vigorous effort into the development of directed energy weapons, kinetic energy weapons, as well as into research on a set of technologies such as early warning, aiming, tracking, and target recognition. This article, on the basis of openly published U.S. sources, takes a comprehensive look at the status of several areas of development in U.S. space defense systems.

Following along with the receipt and utilization of the National Test Bed (NTB), mechano-optical auxilliary sensor devices, and other key experimental systems, a beginning has already been made in carrying out broad experimentation with SDI hardware and software as required for taking the weapons through development in the direction of deployment. In the next period of time, projects which will enter hardware experimentation are:

1) Delta Star was a phenomenological mission launched in early 1989 and made up with a Delta booster.

2) On Target includes experiments in a spaceship suspended in space on interception device sensors, electronic guidance equipment and boosters for space bases. The tests began to be carried out in early 1989.

3) Star particle beam rockets or Bear (Beam Aboard Rocket). This is one type of small model neutral particle beam satellite being tested. Launch is planned for April of 1989.

4) High level defense intercept devices. This is one type of surface strike and casualty producing weapon. First tests will be carried out in the summer of 1989.

5) Relay reflection mirror experiments and laser atmospheric compensation tests. These are two directed energy tracking and aiming

satellites. It is possible to use a Delta booster to launch them in late 1989.

6) Outer atmosphere reentry intercept sub-systems. One type of Phasel weapon ground intercept device will be tested in the second quarter of 1990.

7) Booster observation and tracking satellite. This is the first SDI system that will be test manufactured and deployed. Testing will be completed in the spring of 1990. Moreover, in the 1990's, the first satellite will be launched on a Titan 4 rocket.

8) Onboard optical auxilliary sensor devices. This is a type of SDI sensor device. It is just in the midst of ground testing. It will undergo flight testing in 1989.

9) Starlab. This is a type of space plane mission. Its objective is to be used to acquire, track, and aim. The plan is to carry out tests in the fall of 1990.

10) Space based intercept devices. This is a type of Phasel kinetic energy weapon. It will, in the next 18 months to 4 years, undergo 2 to 3 iterations of flight testing.

11) The Zenith Star. This is a type of space-based chemical laser device experiment. It is planned for launch in late 1993.

12) Space observation and tracking systems. This is a type of intermediate sensor device satellite. In the middle 1990's, ground and space flight tests will be carried out.

Below, we will introduce the status of development of these several projects related to SDI.

1. EARLY WARNING AND ANTIMISSILE SATELLITES

The U.S. Defense Department plans in 1990 to conclude a sensor satellite contract with a value of 8 billion U.S. dollars. This is capable of raising the level of ballisitic missile attack early warning and setting off antimissile systems. What are called booster surveillance and tracking systems (BSTS) are a type of dual function satellite. They will replace the current defense satellite project (DSP)'s missile early warning system. In conjunction with this, weapons will be taken and added into the strategic defense system. This type of system possesses relatively high survivability. 16
Moreover, compared to DSP, it possesses even greater resolution or

resolving power and relatively faster reporting times. This system is planned to start working in the middle to late 1990's.

The U.S. Air Force and SDIO plan to spend at least 8 billion U.S. dollars to test produce and deploy BSTS. Moreover, protecting this system could possiblly require even more expenditures. BSTS is a type of highly advanced, comprehensive technological product. It has maneuver capabilities which are able of escaping enemy attacks and threats. Moreover, it is necessary that it possess the capability to handle space and onboard lasers, ground anti-satellite weapons, X-ray laser devices, neutral particle beams, space based shells, and high powered microwave weapon attacks.

This type of satellite is possiblly the number one system required for the development of SDI. The current plan is for the deployment of BSTS before the year 2000. According to what is said, full scale development investments do not begin until the 1992 Air Force budget. BSTS has two requirements. Speaking in terms of SDI, it is necessary to track missile firings. Moreover, it must inform other sensor devices and weapons of the approaching missiles. The other requirement is to supply survivable observation and early warning systems. The North American Aerospace Defense Command (NORAD) and the Strategic Air Command (SAC) obtain early warning intelligence reports. In conjunction with this, reports are made to the overall national headquarters in order to make appropriate responses.

In the entire BSTS group of satellites, the number of individual satellites is classified. However, it must be a larger structure than the three DSP satellites. BSTS will be deployed in different orbits in order to increase the covered area. In this way, BSTS's production costs for each individual satellite are higher as compared to DSP satellites. The reason for this is that they raise survivability and resolution. The new satellites will also have relatively higher onboard processing capabilities. Among these are current ground processing functions placed onboard the satellites to be carried out. Processing onboard the satellites is necessary. The reason is that they must supply directly to the SDI weapons platforms special tracking data. Because of this, the test manufacture and data collection costs must be very high. However, it is possible to lower operating expenses from going through ground personnel, adding a

compensation. According to what is said, when one takes test production, deployment, and utilization costs and adds them together, the expenses for the new system will certainly not be higher than those for DSP.

The production contract is figured to be concluded in the fall of 1990. The Air Force plans to begin procuring four satellites and two ground terminals. Among the ground terminals, one is a fixed station. The other is a mobile station. One plan that has been prepared as a backup is to purchase 9 satellites and 8 ground stations. In peacetime, one would depend on the fixed stations. In wartime, operations would make use of the mobile receiving stations.

Two companies, Lockheed and Grumman, will carry out tender bid competitions in the next 16 month period. In this period, they will carry out design and testing in order to facilitate, in May of 1990, obtaining a production bid for this system. The Air Force only recognizes these two companies. The reason for this is that these two companies have already begun early stages of BSTS work. However, it may also approve competition from other companies. The principal competitor among them is TRW. It is the manufacturer of DSP satellites. In the tender bid competition, the two companies selected for use two types of radically different sensor device designs. The Lockheed Company opted for the use of scanning sensor device designs. However, the Grumman Company is in the midst of designing fixed view array sensor devices.

SDI and the Air Force hope that, before the first operational satellite deployment, BSTS will go through flight tests in space. The Grumman Company has already suggested sensor device tests during an early period to be carried out on satellites produced on a world-wide fixed position system production line.

SDIO has already considered using ground laser device illumination tests as one part of checks on the survivability of satellites. Flight tests are capable of accumulating useful data on the operation of BSTS. In this are included various types of background characteristics or conincidental incidents which sensor devices are capable of observing. Systems must discriminate between various types of phenomena. Among these are included nuclear X-rays, radiation, neutrons, captured electrons, fuel discharge, atmospheric emissions, lasers, solar light scattering, nuclear reactions, chemical flouresence and radiation, etc.

However, flight test investments are very high. There is the possibility that SDIO and the Air Force can, from ground tests, plan going directly into operational model satellites. This type of method saves money alright. However, it is relatively risky. It goes without saying that, in any type of situation, Department of Defense planners will take BSTS and gradually substitute it in DSP operations. However, this process may be quite long. In the present early period, as far as early warning satellites are concerned, there are at least 8 DSP's manufactured by the TRW Company. Because of the fact that they launch one every 18 months, DSP's will be adequate for use up to the year 2000. Besides this, the Defense Department also recognizes that due to the fact that DSP does not have survival capabilities, there will be a definite degree of risk. This type of satellite is very easily destroyed. However, by comparison, it is thought that killing BSTS is extremely difficult. The reason is that, during its design, consideration has already been given to threats from laser devices, anti-satellite weapons, high power microwaves, as well as nuclear reactions. In a comparison with DSP, new satellites, in terms of reliability, have made the progress below.

The primary BSTS instrumentation will be made up of a large telescope and wide view field sensor devices. It will also be fitted with a number of relatively small auxilliary compartments to carry out secret missions. In addition, it will also carry a narrow view field camera.

The principal mission of the system in question is to make use of booster flame strengths, launch orbits, and other similar information to classifiy targets in order to arrive at an indentification of the objectives of different boosters. BSTS is also capable of being used in order to identify targets. The satellites in question will be loaded aboard a Titan 4 booster which will take an approximately 10,000 lb satellite and launch it into a synchronous orbit.

Based on two types of different sensor technologies, that is, 17
scanning arrays and fixed view arrays, a series of competitive evaluations were carried out. The fixed view array of the Grumman Company is elliptical. Its width is somewhat more than 1 ft (30.48cm). It is composed of over a million probe devices made up of

approximately 2000 small assemblies. In the early period, the principal problem with developing fixed view arrays for space systems was high expenses. Moreover, 15 years ago, this problem was already appreciated. The structure of the focal plane is the direct integration of probe devices, processing devices, and thermal subsystems into an array. However, scanning arrays opt for the use of independent processing devices and data distribution. Within the next several months, the Grumman team will take the focal plane and optics as well as computers and integrate them. In conjunction with this, tests will be carried out. Lockheed team member Xiusi (phonetic, possibly Hughes) Aircraft Company is just in the midst of test producing scanning sensor devices. Xiusi (phonetic, possibly Hughes) Aircraft Company is also in the process of manufacturing onboard optical auxilliary sensors. Moreover, this type of technology is also appropriate to use in BSTS. In scanning sensor devices, probe or detection devices become focal plane components. In conjunction with this, in arrays, the test measurment panel design is arranged. Refrigeration systems are located behind the focal planes. They and data porcessing devices are both independent. In a comparison with fixed view devices, the number of individual probe or detection devices associated with scanning arrays must be much smaller. Because of this, in the aspects of design, production, and production costs, there is even more advantage to their application in practical use. Moreover, they are light in weight, and their power requirements are low. The Grumman Company recoginzes that fixed view arrays must, as compared to scanning arrays, possess even higher precision. Scanning systems, because they are not constantly observing the same spot, are, for this reason, capable of losing a number of emissions or firings. Moreover, it is very difficult to precisely measure the location of launch sites.

In sensor device technology, the key point of competition was the selection of probe or detection device materials. InSb and HgCdTe materials are two types which both are capable of satisfying the BSTS fuctional requirements. However, HgCdTe probe or detector devices are able to take relatively high temperature operation. In this way, they simplify the thermal systems associated with probe or detector device cooling.

It is said that the production basis for InSb probe or detector devices is capable of being used in other projects. However, the Lockheed Company continues production work on the HgCdTe probe or detector devices, and is preparing, in the spring of 1989, for the carrying out of a priority evaluation of the two types of probe or detection devices. The Grumman Company has already decided that HgCdTe will act as the probe or detector device material.

BSTS groups possess a cross communication capability between satellites. Contractors have already evaluated laser and radio cross communication technologies. The Lockheed Company has already selected for use laser devices designed by the McDonnell Douglas Company. As compared to radio technologies, laser communications possess outstanding advantages in the areas of production costs, weight, power, and volume. Moreover, optical systems also possess anti-interference capabilities. The Grumman Company has still opted for the use of radio communications. The reason is that the weight and power of radio communications systems are capable of reaching the level of laser devices.

2. ANTISATELLITE PROJECTS

The three U.S. services are all very interested in antisatellite projects. They hope to produce a type of mobile model ground and sea fired kinetic energy weapon for joint use. This is derived from SDI's outer layer reentry intercept device system technology. This type of intercept device is a kind of ground launched weapon. It is used in order to destroy reentering warheads. It is an expansion of ground laser antisatellite systems. Personnel concerned recognize that the realization of laser antisatellite projects requires an even longer time. Moreover, the U.S., first of all, requires kinetic energy antisatellite weapons. The reason for this is that they, as compared to directed energy antisatellite weapons, possess the advantages below. First of all, they are not subject to the limitations of atmospheric conditions. Moreover, their effective distance is great. The development of mobile type antisatellite intercept devices was carried out independently of the most recently approved improved infrared laser antisatellite test projects. In 1988, approval was given for use of a 2MW level infrared advanced chemical laser (Miracl) to carry out tests against space bodies. It is said that, in the next

generation of laser systems, before successful test manufacture of free electron laser devices or quasi-molecular lasers, Miracl laser devices will continue to be effective. In the area of Miracl improvements, they will increase laser tracking stability in order to increase the killing capacity against low orbit satellites.

The objective of conducting tests of Miracl against targets in orbit is to understand the power disipation as laser beams pass through the atmosphere. It is also possible to understand information related to threats which currently existing Soviet lasers pose to U.S. satellites. According to photographs taken by the French SPOT satellite, one can clearly see that the Soviet Union has a laser facility at Dushanbe. There is a possibility that it is a type of high power laser device.

3. OUTER ATMOSPHERE INTERCEPTION DEVICES

The Lockheed Missile and Space Company has already begun to carry out, on outer atmosphere reentry intercept systems (ERIS), hardware assembly and systems integration. This is one of the key SDI technologies. Lockheed Space Flight Systems Company has already handed over the first composite body structures to the Lockheed Sunnyvale plant to use them to act as a flight stage assembly model. The structure in question has a length of 6 ft (1.83m) with a diameter of 27 in (0.69m). It is made using a material of graphite polyethylene plate which possesses a beehive type core.

ERIS will be a type of ground launched in-flight intercept device used in order to destroy warheads that have just penetrated into the outer layers of the atmosphere. Moreover, it opts for the use of high speed direct-hit-on-target methods and does not use various 18
types of explosive methods to destroy targets. The first composite body structures will be used in order to assemble flight stage hardware. However, it does not play the role of flight utilization. It is only used for qualitative research on hardware. The key to composite body structures is the base. The reason for this is that on its upper surface one will have the booster. The manufacture, assembly, and installation of this type of structure and the necessary precise directional orientation on the base is extremely difficult. In this type of application, opting for the use of

composite materials is totally ideal. The reason for this is that they are unusually light, extremely hard, and vibration isolating. Vibration isolation is very important. The reason for this is that, after booster ignition, it will cause vibation. As a result of this, it will influence the target seeking or homing devices aiming on targets. The target seeking or homing devices use a small cylinder-shaped box loaded directly into the main body of ERIS. Liquid nitrogen is used to cool HgCdTe probe or detector devices to 77K.

A set of small booster devices are positioned on the basic body adjacent to the target seeking or homing device. When it pulls in a target, the entire ERIS assembly body rotates around three axses. These boosters or auxilliary thrusters will not influence the trajectory of the spaceship. After electronic components which include within them mechanical inertial measurement elements are located at the target seeking or homing device, one has, in succession, propulsion device sections. Before target seeking or homing devices go into guidance functions, commands from the ground management system will cause one or two ignitions in primary and auxilliary propulsion devices. As soon as the devices enter into a guidance configuration, primary and auxilliary thrusters will then fire, causing the spaceship to approach the target.

The spaceship's four sections include communications equipment, batteries, decryption systems, homing device cooling systems and other equipment. The spaceship's final section is a cone shaped kill strengthening system (KED). The weight of KED is only 13 lb. It approaches speeds of 20,000 ft/s. Because of this, it is only necessary to have a very small mass and it is then possible to destroy the target. Lockheed simulation testing laboratories are just in the midst of doing these sorts of experiments. In these, the equipment includes target image generators and platforms free to move in every direction through 5 dimensions.

Besides this, SDIO has prepared, in 1989, to begin to utilize a new national spacebased intercept device flight test facility to carry out wide ranging experiments. The weight of the model spacebased intercept device (SBI) is 150 lb. Its length is 4 ft (1.2 m). Its

weight, as compared to the actual weapon, is heavier. Its volume is larger. Because of this, only standardized equipment is used to calibrate and measure various types of components and systems in order to supply basic data for SBI research. In the future, use will be made of relatively small, relatively light airships to replace the current models. The tests in early 1989 are designated On Target. The tests will measure sensor devices and guidance electronic systems test manufactured for SBI by the Martin Marietta Company. In spacebased intercept device test facilities, one also includes laser distance measuring systems. When intercept devices are suspended in space, the systems involved are capable of tracking them. In future measurments and tests, laser distance measuring systems are capable of communicating with airships. In conjunction with this, they act as their inertial reference units.

4. ABOARD OPTICAL AUXILLIARY SENSOR DEVICES

Before aboard or onboard optical auxilliary sensors (AOA) were installed in Boeing 767 aircraft, a series of tests were carried out in order to evaluate sensor device tracking and detection capabilities against missiles.

Hughes Aircraft Company test manufactured infrared sensor devices have been used in order to evaluate onboard long wave infrared (LWIR) system support to ground ballistic missile defense radar capabilities. SDIO and the Army Strategic Defense Headquarters, most recently, have already made plans to do broad research on surface and space based sensor device applications of relevent technologies. For example, AOA projects will make even more use of tests done on sensor device technology.

Before Hughes sensor devices began flight tests in the middle period of 1989, they were placed into the Boeing Systems Integration Laboratory (SIL). The targets of system observations included fixed mission ICBM's and ad hoc firings of targets toward the Kwajalein target range. In the future, it is possible to observe targets including submarine launches and short range ballisitic missiles. This project will evaluate systems in observations of missile capabilities during boost stage, mid stage, and terminal flight stages.

The primary objective of the test projects is to evaluate system capabilities in large area search and simultaneous tracking of over

one hundred targets. This system will be capable of distinguishing real missiles from a background of decoys and fragments. Moreover, it will be able to transmit the tracking data to ground systems.

AOA systems possess probe or detection, tracking, and scanning--three types of operational modes. The probe or detection and tracking functions are completed by communications and data processing devices. The scanning functions are completed by omnidirectional frameworks for sensor devices.

In July of 1988, AOA sensor devices were shipped to Boeing Systems Integration Laboratories after which they were rignt in the midst of doing early stage preparatory work. Power source systems and refrigeration systems have also already been integrated. Servo systems used in precision aiming and stabilization have already been put through precision adjustments. It is estimated that, in early 1990, sensor devices will be transfered to Boeing infrared sensor device standardization labs (BIRS).

Hughes Aircraft Company's electrooptical and data systems groups were, for Boeing Aerospace Company, the test manufacturers of sensor devices, and, for AOA sensor devices, test manufactured focal plane arrays, analogue and digital communications processing systems, as well as aiming and stabilization systems. Company's participating in this mission were: Tinsley Laboratories (test manufactured large telescope reflective mirrors), the Honeywell Company (test manufactured inertial attitude reference systems), as well as Raytheon and CVD (test manufactured sensor device large dimension ZnSe windows). 19

Sensor device's 15in (38cm) long focal plane assemblies include 60 sensor device core arrays. Each array is made up of 640 individual infrared probe or detection devices. Moreover, each individual probe or detection device, using indium welding, is connected to the corresponding preamplifier. As far as AOA flight test projects are concerned, 38,400 individual Si^{2}Ga probe or detection device elements are arranged into 15 assemblies. However, AOA focal planes are capable of containing 44 individual assemblies.

The execution of real time processing on large amounts of data is facilitated by sensor signal data processing devices researched and

manufactured by Hughes, Honeywell, and Boeing. The systems in question are capable of filtering out background signals and internally produced noise. In conjunction with that, it is capable of distinguishing true targets from false ones. Using analog signal processors (ASP) installed on sensor device telescopes, one starts to carry out time order filtering and limitation on large amounts of data produced by focal plane arrays. The processing devices in question are capable of carrying out analog transfers at a speed of 387 million iterations each second, controlling focal plane operations, and carrying out multicircuit transmission of digital processing signals.

AOA system digital communications processing devices are positioned inside the cockpit of 767 aircraft, including time dependent processors (TDP) and object dependent processors (ODP). TDP complete the majority of the filtering operations. They are a type of high level parallel computer. The operational speeds reach 15 billion iterations a second. The functions of these units are to raise signal to noise ratios, lower data speeds, and set up data levels or stages in the processing point source base. Real time processing units have 86 logic processing boards. Among these are included 25,000 individual integrated circuits. As far as specially designated targets of ODP system processors are concerned, they include 31 parallel operation single board computers. Their operational speeds are greater than 20 million iterations per second. These elements, on the basis of preprogrammed decisions such as target location, brightness, and speed, carry out close to real time analysis of point source targets. After this is done, the systems in question take prescribed data and send it to processing devices. The data processors are also located in the aircraft cockpit. They are capable of accurately detecting target orbits. In conjunction with this, they distinguish true targets, and, after that, take the data and send it to ground radar stations.

In sensor device probe periods, electric sensor device omnidirectional frames and aiming systems compensate for changes in the position of the aircraft and pitch angle. Telescope omnidirectional mounts carry out scanning, and, going through sensor device window apertures in sensor device covers, carry out

observations. This type of scanning system requires, when rotated or slanted, to be able to move forward and back in order to be able to cover the field of view. Going through omnidirectional frame mechanical stabilization and electronic methods of compensation for residual motions inside signal processing devices, one then obtains aiming line stabilization. Use is made of three ring laser gyroscopes to precisely specify sensor device telescope aiming lines corresponding to aircraft attitude and flight path.

Sensor device optical telescopes take incoming photons and reflect them onto refrigerated focal plane arrays. Three surface relective mirrors use fused quartz in their manufacture in order to be advantageous for not being influenced by extremely low temperature environments provided by closed circulating helium refrigeration systems. Two individual refrigeration devices are improvements on systems in civilian use. They are manufactured by CTI Company which specializes in this project. The back surfaces of reflective mirrors have approximately 70% of their surface area made of processed large honeycomb type structures. In order to reduce weight, the depth of the honeycomb from the reflective mirror surface is 0.25in (0.635cm). Moreover, the surface deformations are smaller than 5×10^{-6} in. The ZeSe end windows of sensor devices are transparent to their observation infrared wavelengths. Their diameters are 23 in (58cm). Thickness is 1.5 in (3.8cm).

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WANG Rongrui. Male. Born January, 1937. High level engineer. Graduate of the Zhejiang University Semiconductor Specialization. Is member of China Electronics Society Electronic Intelligence Committee. Long engaged in specialized laser and infrared intelligence work.

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